NITROGEN UTILIZATION FROM SANDY MEDIUMS

by

FRANCIS BRENT HOADLEY

B. S., University of Vermont, 1964

A MASTER'S THESIS

submitted in partial fulfillment

of the requirements for the degree

MASTER OF SCIENCE

Department of Horticulture

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1967

Approved by: Ray A. Keen

Major Professor

Table of Contents

Introduction

Nitrogen is an essential constituent of every living cell. The soil organo-mineral complex preserves and supplies this macronutrient.

The United States Golf Association green section has recommended a high sand - low colloidal soil medium for the construction of golf greens in order to curtail compaction problems caused by the increasing play on modern golf courses.

Nitrogen fertilizer effectiveness is limited on this type of soil medium. Sandy soil has a low cation exchange capacity and nutrients held by the soil complex are subjected to greater leaching. A lack of organic matter in sandy soils precludes chemical and physical bonding of nutrients to the soil complex. Since nutrients are not held inactive by the soil complex, the smaller microbial population of sandy soils can be more effective in making available needed nutrients.

The purpose of this study was to investigate the nitrogen release characteristics of urea, activated sewage sludge, ureaform, and ureaform plus sucrose. These materials were applied to a Seaside bentgrass green constructed with the recommended soil mixture.

The study was duplicated in the greenhouse in pots of sterilized and unsterilized soil mixture.

Review of Literature

"Nitrogen is the most critical of the fertility elements used in turf management, and its proper use is second only to water in importance (39)." Grasses grown on a golf green present a unique problem in nitrogen fertilization.

The sandy soil mixture chosen for this study was previously depleted of nitrogen by growing turfgrass for a period of two years with no additional nutrients being added to the soil (35). Three nitrogen fertilizers were chosen to supplement this growth medium.

Urea is a soluble synthetic organic compound containing forty-five percent nitrogen. This compound is available to the plant foliage in spray applications or can by hydrolyzed to ammonium ions which are readily available for assimilation by the roots. The ammonium ion can be converted by microorganisms to nitrate which is also an available form. Volk (40)(41) and Ernst (16) have noted the effects of several factors on the volatilization of ammonia from surface applied ureas. They have noted that losses increase directly as particle size increases, moisture increases and temperature increases.

Wagner (43) has shown this volatilization loss to be due to nitric oxide, nitrogen dioxide, and nitrous dioxide evolution. Ammonia may account for a small part of this loss.

Martin (30) has stressed the importance of a threshold pH value of 7.7 ± 0.1 for ammonium ions to be converted to nitrate ions. He has also observed a decrease in the pH value of alkaline desert soils prior to nitrate formation. Intermediate products in the ammonium oxidation process such as hydroxylamines and hyponitrous acid could explain this.

Once the pH is sufficiently low, the nitrate product is subject to further loss from soils with a low cation exchange capacity. Bredakis (10) reported that urea had as much or more nitrogen leached in a fifteen week period than any of six nitrogen fertilizers tested.

Volk (42), working with oats and millet, found a much higher recovery of urea nitrogen by these crops when compared to other organic nitrogen sources.

Ureaform is another synthetic organic fertilizer but it is professed to be slowly available. Roberts (2) uses the term "spoon fed" to describe the way this thirty-eight percent nitrogen fertilizer releases its nitrogen. This type of release should be tailored to sandy mediums and produce even growth of turfgrasses.

Clark (12) set certain standards to describe nitrification and the activity index of slow release fertilizers. The NI (nitrification index) was defined as the percentage of added nitrogen which is not present in the nitrate form at the end of three weeks incubation but is converted to the nitrate form within fifteen weeks. Clark (12) uses the nitrogen activity index to determine the amount of hot water insoluble nitrogen. AI is an empirical quantity which relates the percentage of cold water soluble nitrogen that goes into hot water solution.

AI = (% WIN - % HWIN/% WIN) x 100

WIN = Cold water insoluble nitrogen

HWIN = Hot water insoluble nitrogen

Another means used to indicate the availability of nitrogen from ureaform is mole ratio. Ureaform differs from urea formaldehyde plastics in the relative proportions of urea and formaldehyde which are condensed in the product. Clark (13), Long (26) and Yee (45) demonstrated that the mole ratio of urea/formaldehyde should be in the range of 1.25 to 1.40. Long (26) further noted that ureaform with a mole ratio of 1.75 and AI of 71 had only 1/2 of the insoluble nitrogen removed when compared with a soluble mineral nitrogen. A 1.50 index and AI of 39 allowed 1/2 the recovery of a 1.75 index. The recovered insoluble portion of a commercial ureaform (38% N) was 1/3 of the latter.

Hays (22) supports the correlation between solubility and the nitrification rate of ureaforms. He isolated three complex nitrogen fractions and reported that as the molecular weight of the fraction increases the solubility of the fraction decreases.

The foregoing measurements made on ureaform are better explained by growth manifestations of turfgrass. Goetze (19), Kilian (25) and Wisniewski (44) pointed to more uniform growth of the turfgrass when ureaform is used as the source of nitrogen. An even growth such as this is the kind desired on a golf green. Baumgartner (7), Jackson (23) and Mruk (31) each found a good sod quality and density when ureaform was used as compared to other nitrogen fertilizers.

Armiger (5) and Blaser (9) reported a slower growth of the turfgrass during the first three to four week period after ureaform was applied to the turf. Lunt (29), Long (26) and Jacobson (1) have substantiated this by showing a need for building a reserve of ureaform in the soil. Lunt (29) suggested there must be enough ureaform residue in the soil to release 6 to 7% of its nitrogen per month. One reason for disappointment with ureaform may be the failure to build up adequate reserves of this product in the soil.

The residual effect of ureaform is another way of explaining the slow release qualities of this product. Jacobson (1) found a decrease in dry weight clipping differences during the third year of ureaforms use, as compared to other nitrogen sources. Scarsbrook's (38) work with cotton and corn indicate a higher residual effect from ureaform (AI 49) than with ammonium nitrate.

Slow release fertilizers are less subject to leaching on sandy soils. Bredakis (10) rated ureaform lower in total leachable nitrogen than four

other nitrogen sources. At the end of a fifteen week leaching period a soluble material lost 19% of its N while ureaform lost approximately 2.2% (10).

It is possible to obtain a fair index of the relative productivity of a series of soils by counting the number of microbial cells contained in a unit weight of dry soil (8). Fuller (18) and Lunt (29) established the need for microbes in the mineralization of ureaforms. Mineralization rates are subject to all factors which influence the activity of microorganisms including: moisture, temperature, aeration and pH. Kender (25) correlated a greater growth response with cranberries from ureaform over three other readily available N sources with the larger microorganism population found in cranberry bogs.

Sandy mediums, such as the one used in this study, usually have a lower organic matter content but they also do not serve as a protective agent to microbial degradation of fertilizers.

Grau (20) and Duich (15) hypothesize ureaforms building a selective microorganism population in the soil and they feel that mixing other nitrogen sources with ureaform would destroy this effect. Armiger (5) and Blaser (9) are opposed to this view and feel that the addition of a soluble source of N would help to overcome this observed lag in growth during the first three or four weeks.

The economic feasibility of building up a reserve of ureaform in the soil to compensate for availability is another point in question. Long (26) concluded that it is not a sound investment for the average home owner but that it may be for high maintenance turf areas.

The amount of nitrogen recovered compared to the amount applied is a question of economics too. Goetze (19) recovered as much as 33% of the

nitrogen applied as a soluble fertilizer. Only 17% of the ureaform nitrogen applied was recovered. Kilian (25) supports this work stating that ammonium and nitrate forms had 51% of their nitrogen recovered while a mixed N fertilizer (53% of the N from ureaform) had 39% N recovered.

Activated sewage sludge is a natural organic nitrogen fertilizer of low analysis (6% N). Nitrification products for turf utilization are made available by microbial action on the organic nitrogen complexes contained in this fertilizer.

Activated sewage sludge is made by applying processed sludge to inoculated primary sludge in the presence of large amounts of air to help decompose and flocculate the end product (28).

The value of activated sewage sludge for fertilizer was realized about the turn of the century. Hatfield (21) noted the availability of nitrogen from this product when comparisons were made with other sources of nitrogen.

Lunt (27) and Rudolf (37) have listed some of the beneficial qualities of sewage sludge. It improves the soil by increasing the water holding capacity, increasing aeration, improving soil structure, introducing beneficial microorganisms into the soil, and introducing mineral elements needed for growth.

Rehling (36) and Clark (14) reported the presence of a considerable quantity of trace elements, 6.5% of sludge by weight, necessary for plant growth, in activated sewage sludge. The base exchange capacity was found to be 22.4 m.e. and many substituted fatty acids were extracted from the fertilizer. Silt, clay, sand, cellulose, and protein were the other major components found in activated sewage sludge.

Excellent sod density and turf quality have been noted by Clark (11), Jackson (23) and Musser (33) when activated sewage sludge was compared with

other nitrogen sources.

Other beneficial effects have been shown. Volk (43) reports that oat and millet plants recovered 2 to 4 times more N from high grade natural organics than from ureaform. Niles (34) moistened activated sewage sludge and allowed it to stand for 20 days resulting in 20% more N. This was thought to be due to the presence of nitrogen fixing bacteria. Muller (32) recognized that the C/N ratio for sludge must be below 8 so that nitrogen will not be utilized by microoorganisms mineralizing the rich organic matter. Leaching results in large losses of N but activated sewage sludge loses slightly more N than the ureaforms and considerably less than soluble products like urea(10).

Materials and Methods

Kaw Valley Blow Sand and Blue River Mason Sand were the major components of a soil medium used to study the nitrogen release characteristics of three nitrogen fertilizers. The Bouyoucous hydrometer method for mechanical analysis (4) indicated the soil mixture consisted of 85.6% sand, 7.4% clay and 7.0% silt.

The study was divided into three distinct parts: a golf green, a greenhouse study using unsterilized soil and a greenhouse study using sterilized soil. All three segments of the study were conducted with the same sandy soil. The Kansas State University soil testing laboratory found the following fertility index for this soil: 0.8% organic matter, 18 lb./acre of available P, and 162 lb./acre of available K.

The Experimental Green

The construction of the experimental green followed closely the procedure outlined by Ferguson (17). Topsoil was throughly mixed and

stockpiled near the site of construction. The subgrade was established with a one foot drop west to east and north to south, just as the finished surface was to be. Four inches of road gravel were graded uniformly over the area as a gravel drainage layer. The topsoil mix was used to ring the green. Topsoil was cast into place by a crane and smoothed to a final grade. No heavy equipment was allowed on the green in hopes of preventing any uneven compaction. A four inch agricultural drain tile running parallel to the east edge of the green was added for good drainage.

The experimental green (4096 square feet) was divided into forty plots, each 8' x 10' or an area of 80 square feet. A rectangular plot area, 8 rows north to south and 5 rows west to east, was laid down. Plots were separated by a one foot guard strip. Three nitrogen fertilizers plus a control constituted thirteen treatments replicated three times. Treatments were completely randomized, resulting in 39 treated plots and 1 extra control plot (Plate I).

Treble superphosphate was applied to all plots at the rate of 13 lb./1000 square feet and potassium sulfate was used at 12 lb./1000 square feet. High rates such as these were used to compensate for the original low levels of these two nutrient elements. The sulfate form of potassium was used to lower the alkaline pH and decrease salts accumulation which might have occurred if KCl was used.

The three nitrogen fertilizers were segregated into the following treatments: a soluble synthetic organic urea (45% N) - 2 and 4 lb. nitrogen per 1000 square feet, a natural organic activated sewage sludge (6% N) - 2 and 4 lb. N/1000 square feet, a synthetic organic ureaform (38% N) - 2, 4, 8, and 16 lb. N/1000 square feet and ureaform used at the same rates but combined with 20 lb./1000 square feet of sucrose.

Table 1: Fertilizer treatments applied as grams/plot or grams/pot.

Treatment	Compounds (Fertilizer)	Grams/ 80 Sq. Ft.	Grams/ 5 Kg. Pot
Ureaform 2	Ureaformaldehyde	191.0	0.573
UF_2	Superphosphate	472.0	1.416
	Potassium sulfate	436.0	1.307
Ureaform 4	Ureaformaldehyde	382.0	1.146
UF_4	Superphosphate	472.0	1.416
	Potassium sulfate	436.0	1.307
Ureaform 8	Ureaformaldehyde	764.0	2.293
UF_8	Superphosphate	472.0	1.416
	Potassium sulfate	436.0	1.307
Ureaform 16	Ureaformaldehyde	1528.0	4.585
UF_{16}	Superphosphate	472.0	1.416
	Potassium sulfate	436.0	1.307
Ureaform 2 + Sugar	Ureaformaldehyde	191.0	0.573
UFS_2	Superphosphate	472.0	1.416
	Potassium sulfate	436.0	1.307
	Sugar (Sucrose)	726.4	2.178
Ureaform 4 + Sugar	Ureaformaldehyde	382.0	1.146
UFS_4	Superphosphate	472.0	1.416
	Potassium sulfate	436.0	1.307
	Sugar (Sucrose)	726.4	2.178
Ureaform 8 + Sugar	Ureaformaldehyde	764.0	2.292
UFS_8	Superphosphate	472.0	1.415
	Potassium sulfate	436.0	1.307
	Sugar (Sucrose)	726.4	2.178
Ureaform 16 + Sugar	Ureaformaldehyde	1528.0	4.585
UFS_{16}	Superphosphate	472.0	1.416
	Potassium sulfate	436.0	1.307
	Sugar (Sucrose)	726.4	2.178
Sewage Sludge 2	Act. Sewage sludge	1470.0	4.352
M_2	Superphosphate	424.8	1.274
	Potassium sulfate	436.0	1.307
Sewage Sludge 4	Act. Sewage sludge	2940.0	8.704
M_4	Superphosphate	282.6	0.878
	Potassium sulfate	436.0	1.307
Urea 2	Urea	161.0	0.483
U_2	Superphosphate	472.0	1.416
	Potassium sulfate	436.0	1.307
Urea 4	Urea	322.0	0.966
U_4	Superphosphate	472.0	1.416
	Potassium sulfate	436.0	1.307
Control	Superphosphate	472.0	1.416
C	Potassium sulfate	436.0	1.307

PLATE I

Fig. 1. The completely randomized plot layout.

PLATE I

C_1	M_2	UF_{16}	UFS_2	U_4
UFS_2	M_4	UF_8	UFS_{16}	UF_4
UF_4	U_4	UF_2	UFS_8	M_4
UFS_4	UFS_8	UF_8	C_3	U_2
U_2	UFS_{16}	UF_4	M_2	C_4
UF_2	U_4	UF_2	M_4	UF_{16}
UF_{16}	M_2	UFS_{16}	UFS_4	UFS_2
C_2	UFS_8	UFS_4	UF_8	U_2

C_{1-4} - CONTROL PLOTS

U_2 - 2 LB./1000 FT^2 OF UREA N

U_4 - 4 LB./1000 FT^2 OF UREA N

M_2 - 2 LB./1000 FT^2 OF ACT. SLUDGE N

M_4 - 4 LB./1000 FT^2 OF ACT. SLUDGE N

UF_2 - 2 LB./1000 FT^2 OF UREAFORM N

UF_4 - 4 LB./1000 FT^2 OF UREAFORM N

UF_8 - 8 LB./1000 FT^2 OF UREAFORM N

UF_{16} - 16 LB./1000 FT^2 OF UREAFORM N

UFS_{2-16}

THE SAME RATES OF UREAFORM N WITH 20 LB./1000 FT^2 OF SUCROSE.

On September 23, 1964 the fertilizers were spaded into the top six inches of soil. The area was raked, leveled and rolled to prepare the surface for seeding. Agrostis palustris, variety Seaside bentgrass, was seeded September 24, 1964 at a high rate, 5 lb./1000 square feet, to insure a good stand of grass before winter.

Grass established in the fall of 1964 winter killed, and a reseeding was necessary on May 22, 1965 at the rate of 1 lb./1000 square feet. Succeeding surface applications of the same fertilizers were made on May 22, 1965 and August 22, 1965. During a period of one year, each fertilizer rate was applied three times. Table 1 shows the amount of fertilizer material in grams added to each plot during one application. To find the total rate of elemental N applied during the year, multiply by three. For example: ureaform N applied three times to a plot would have been either 6, 12, 24, or 48 lb./1000 square feet of actual N.

Five criteria were used to correlate nitrogen fertilizer utilization and turfgrass growth responses. Each plot was rated by observation once per week until all plots were covered on September 12, 1965. Then every two weeks ratings were taken to see if turf quality improved. A rating scale of 0 - 9 indicated percent cover and overall turf quality.

Rating	% Cover
0	0 - 10
1	10 - 25
2	25 - 40
3	40 - 55
4	55 - 70
5	70 - 85
6	85 - 100
7	100 with poor putting quality
8	100 with good putting quality
9	100 with excellent putting quality

A visual rating of 1 (poorest color) to 5 (best green color) was made every two weeks on a clear day. Ratings were based strictly on a

comparative basis and the best green color early in the season would be equal to lower ratings as the growing season progressed.

Fresh weight clipping of the grass, taken to the nearest tenth of a gram, were completed once per week from June 3, 1965 to July 12, 1965. The frequency of sampling was changed to every fourth day starting July 26, 1965 and terminating September 15, 1965. The increase in the number of sampling dates was an attempt to better evaluate the last fertilizer application.

Uniform samples were obtained by mowing north to south on each plot and moving arbitrarily east to west to prevent sampling of just one segment of each plot. The sampling area amounted to 40 square feet or one half of each plot. Three strips 10' x 16" were mowed from each plot.

Fresh weight samples were dried in an oven at 70°C until no further loss in weight was indicated. Dry weights were recorded to the nearest tenth of a gram.

The dried material was ground in a Wiley Mill to pass a forty mesh screen. The samples were stored until the Kjeldahl nitrogen content could be determined according to the A.O.A.C. analysis procedure (3).

Standard serial dilutions, using 10 grams of soil at field capacity, were used to demonstrate the effect these three nitrogen fertilizers and sugar would have on the microbial population of the greens soil. Sterile standard nutrient agar was added to sterile petri plates to provide a growth supporting medium for microbes. A milliliter of the final dilution (1 million X) was then added to the petri plate and the contents were mixed thoroughly. The medium was held at 50°C to prevent solidification and allow mixing.

Plates were incubated at room temperature for a five day period. The dilution factor times the number of colonies growing on each plate was used as an estimate of the soil microorganism population. This portion of the study was conducted during the hottest part of the growing season. The second week in August marked this peak in temperature.

Maintenance practices, including mowing, watering and preventive spray programs followed usual golf course schedules. The plots were mowed every day or every other day depending on the growth of the turf and the weather conditions. The grass was mowed at a height of three-eights inch until June 1 when the height of cut was lowered to one-fourth inch.

Topdressing of the mixture used in construction was applied twice during June to true the green surface. On July 8, 1965 fritted trace elements were applied to the south half of each plot. Topdressing soil medium was used as a carrier for these micronutrients. No change in growth or quality of these treated areas over the untreated portion of each plot were observed.

Fungicides were applied at the recommended rates every 10 to 14 days as a preventive measure beginning June 17, 1965. Insecticides were applied June 15, 1965 and July 29, 1965 as a preventive measure.

A heavy infestation of crabgrass became a competition problem on plots which were low in nitrogen and had not covered well earlier in the growing season. Disodium methyl arsenate was applied at the rate of 1 oz./1000 square feet. A series of three successive applications on July 19, July 26, and August 21, 1965 effectively controlled the crabgrass.

Irrigation water was applied as needed and syringing was necessary on some days during the hotter parts of the summer. Irrometers were installed

during the first week of August which further helped to determine the water needs of the green. A set of irrometers consisted of one irrometer placed one and one-half inches below the soil surface and a second irrometer placed six inches below the soil surface. One set was placed on the high side of the green in the southwest half under a UF_2 plot. The other set was located on the low side of the green in the northeast half under an M_4 plot. Each set was checked twice daily; irrigation was necessary if the tension reading was above 20.

The experimental green was subjected to a wide variety of environmental conditions. The summer was unusually cool for northeastern Kansas. Temperatures were above 100°F just once. During the period May 1 through October 1 a total of 31.47 inches of rain fell with heaviest rains in June (11.27") and September (8.47"). The departure from normal during this period was +9.28 and this was the wettest September since 1858, when records began. The maximum daily temperature was 90°F or higher 28 times and 95°F or higher 11 times during the period May 1 through October 31.

The Greenhouse Studies

The methods and materials for the two greenhouse studies were the same except one study was conducted with unsterile soil and the other was conducted with steam sterilized soil. The soil was sterilized by placing the medium in a large autoclave and heating at 121°C with 15 P.S.I. pressure for one hour. No attempts were made to keep the soil sterile after the initial sterilization.

The soil used was obtained from the pile of soil medium used to construct the experimental green. A plastic pot containing five kilograms of soil was

used as a replicate. Forty pots and treatments were randomized completely in the same manner plots and treatments were on the experimental green.

Fertilizer rates for P_2O_5, K_2O, and the three nitrogen fertilizers (twelve treatments) were obtained by converting the lb./acre rates applied to the experimental green to ppm. by dividing by two. A conversion factor for 5 kg. of soil per pot is .005 times that used for the 80 square feet field plots. These rates would be equal if the assumption is made that the roots and fertilizers on the experimental green do not extend below the six inch plow depth.

Table 1 shows the amount of fertilizer material added to each pot. The fertilizer materials were thoroughly mixed with the soil before filling each pot. All pots were set on plates covered with a sheet of plastic to collect any leachate. The water and leached materials could then be drawn back into the soil medium by capillary action.

Greenhouse pots were seeded with Seaside bentgrass at the rate of 1 lb./1000 square feet of surface or 0.138 grams/pot. Seed was scattered evenly over the soil surface and watered thoroughly. A sheet of plastic was placed over the complete set of pots until seed germinated. After the plastic was removed the pots were watered as needed and no further maintenance practices were required.

The duration of the greenhouse studies was 115 days for the unsterile soil and 94 days for the sterile soil. Each set of pots had the grass clipped twice at a height of 1/4" and the second cut terminated these studies since growth slowed appreciably with hot weather. Fresh weight, dry weight and Kjeldahl nitrogen were determined in the same manner as previously noted. Population counts for microorganisms were made after each cutting utilizing the same method described for the experimental green.

Growth increments were measured in these studies every 10 to 12 days. A 3 x 5 card was placed flat and parallel to the soil surface on the tips of the grass blades. The average height of the grass contained in each pot was estimated by measuring the distance from the soil surface to the edge of the card, to the nearest one-fourth inch.

Environmental conditions in the greenhouse were less variable than those encountered out of doors. Good control was effected over the minimum temperature, leaching and the soil moisture content.

F tests were used to indicate significant differences between treatments for all three studies. If differences were indicated then L.S.D's were computed at the 0.05 level.

Results and Discussion

Greenhouse Studies - Unsterilized Soil

Results indicate the need for a continuous supply of nitrogen on a sandy medium. Grass in unfertilized control pots was significantly poorer in quality than grass growing on the other twelve treated pots (Tables 2, 3, and 4).

The soluble urea nitrogen treatments were significantly better at the 2 lb. (U_2) and 4 lb. (U_4) N level than any other fertilizer used at the same rate (Table 2). U_2 was not significantly different from ureaform at the 4 lb. (UF_4) N level, ureaform plus sucrose at the 4 lb. (UFS_4) N level and activated sewage sludge at the 4 lb. (M_4) N level (Table 2). Similarly, U_4 was as good as 8 lbs. of ureaform N (UF_8 and UFS_8), with and without sucrose. Kjeldahl N and growth ratings did not exhibit these same significant differences, but a similar trend is noted.

Usually fertilizers are topdressed on established turf areas, then fertilizers must have nitrogen components leached into the root zone. A slow release fertilizer has a distinct advantage in topdressing operations since over-leaching or insufficient leaching will not result in a substantial loss of nitrogen from the fertilizer. A soluble product such as urea must remain in the root zone to be effective. Two reasons may account for the excellence of these urea nitrogen treatments. Greenhouse treatments were mixed into the soil before potting the soil (the NH_4^+ released in the root zone was not volatilized into the air). Secondly, water leachate was collected from each pot during watering and returned to the pot, preventing a loss of NO_3^-.

Table 2: Mean ($\bar{x}$) values for Seaside Bentgrass grown in the greenhouse on unsterilized soil for 49 days.

Treatment	Fresh Wt. (Grams)	Dry Wt. (Grams)	%N (Kjeldahl)	Growth (Inches)	MO Counts ($\bar{M}$)
Control	2.93 a*	.67 a	.68 a	2.83 a	3.0 a
M_2	14.33 b	3.13 b	1.41 b	4.33 b	7.8 ab
UFS_2	17.83 b	4.07 b	1.45 bc	4.83 bc	7.8 ab
UF_2	20.37 b	4.07 b	1.50 bc	5.25 cd	5.0 a
UFS_4	30.07 c	5.83 c	1.71 bcd	5.75 de	6.2 ab
M_4	33.47 c	6.40 cd	1.73 bcd	6.42 efg	10.7 ab
UF_4	33.90 c	6.57 cd	1.67 bcd	6.25 ef	6.1 ab
U_2	38.10 c	7.50 d	1.77 cd	6.50 fg	3.9 a
UFS_8	54.37 d	9.27 e	1.97 de	7.08 gh	6.7 ab
UF_8	56.17 d	9.93 e	2.19 e	7.41 h	8.9 ab
U_4	57.03 d	10.17 e	2.17 e	6.91 fgh	20.5 c
UF_{16}	75.50 e	13.03 g	3.62 f	7.08 gh	15.1 bc
UFS_{16}	80.87 e	11.73 f	3.39 f	6.96 fgh	9.7 ab
L.S.D.	9.2366	1.1571	0.3381	0.7245	9.0 M

*Numbers followed by the same letter are not significantly different.

Table 3: Mean ($\bar{x}$) values for Seaside Bentgrass grown in the greenhouse on unsterilized soil for 49 - 115 days.

Treatment	Fresh Wt. (Grams)	Dry Wt. (Grams)	%N (Kjeldahl)	Growth (Inches)	MO Counts ($\bar{M}$)
Control	3.87 a*	1.30 a	1.39 a	2.08 a	11.7 a
M_2	8.10 b	2.50 b	1.10 b	2.96 a	14.5 ab
UFS_2	9.07 b	2.50 b	1.17 b	3.25 a	12.7 a
$\grave{U}_4$	9.37 bc	2.87 b	1.09 b	2.83 a	28.5 abc
U_2	9.50 bc	3.23 bc	1.02 b	2.46 a	7.1 a
UF_2	9.53 bc	2.97 b	1.11 b	3.17 a	8.4 a
M_4	11.00 c	3.13 b	1.17 b	2.62 a	12.9 a
UF_4	13.43 d	4.03 cd	1.16 b	3.25 a	8.3 a
UFS_4	13.50 d	4.37 d	1.11 b	3.48 a	13.9 ab
UF_8	21.00 e	6.83 e	1.13 b	3.64 a	6.7 a
UFS_8	23.60 f	7.30 e	1.13 b	4.04 a	14.2 ab
UFS_{16}	42.80 g	13.67 f	0.98 b	9.79 b	17.4 abc
UF_{16}	44.37 g	13.63 f	1.09 b	8.63 b	32.5 c
L.S.D.	1.8565	0.8931	0.1873	3.1381	15.5 M

*Numbers followed by the same letter are not significantly different.

Table 4: Total mean values for Seaside Bentgrass grown in the greenhouse on unsterilized soil for 115 days.

Treatment	Fresh Wt. (Grams)	Dry Wt. (Grams)	%N (Kjeldahl)	Growth (Inches)
Control	7.13 a*	1.93 a	2.01 a	4.99 a
M_2	22.37 b	5.53 b	2.51 b	7.39 ab
UFS_2	26.90 b	6.53 bc	2.62 bc	8.93 abc
UF_2	29.90 b	7.00 c	2.61 bc	8.11 ab
UFS_4	43.50 c	10.16 d	2.82 bc	9.00 abc
M_4	44.43 c	9.50 d	2.90 bc	9.41 abc
UF_4	47.33 c	10.57 d	2.66 bc	9.38 abc
U_2	47.50 c	10.57 d	2.79 bc	9.29 abc
U_4	66.40 d	13.03 e	2.93 cd	9.75 bc
UF_8	77.13 e	16.07 f	3.31 d	11.08 bc
UFS_8	77.93 e	17.20 g	3.10 d	11.01 bc
UF_{16}	119.90 f	25.40 h	4.47 e	12.91 c
UFS_{16}	123.67 f	26.67 i	4.72 e	22.79 d
L.S.D.	8.2859	1.0728	0.4012	4.4554

*Numbers followed by the same letter are not significantly different.

Advantages of the soluble N-fertilizer were lost when data were obtained from termination cuttings (Table 3). U_2 and U_4 were not significantly different from the other N-fertilizers used at the 2 lb. rate. U_4 was not significantly better than U_2 pointing toward very little additional carry over effect of the higher rate of a soluble nitrogen fertilizer.

Urea had a higher percentage of the nitrogen applied recovered than any other fertilizer (Plate II). The 4 lb. rate of nitrogen appears to be the optimum for a high percent recovery of the nitrogen applied. U_4 and M_4 had more nitrogen recovered than 2 lb. rates of these same fertilizers. UF_2 and UFS_2 had slightly more nitrogen recovered on a percentage basis than corresponding UF treatments.

The percent recovery is higher in the foliage for this greenhouse study than Goetze (19) reported. Conflicting results could be due to different grasses being used (bentgrass vs. ryegrass) and the fact leachate was returned to each pot in this study. Goetze found a soluble fertilizer had 33 percent of its nitrogen recovered. In this study recovery from soluble urea ranged from 48 to 55 percent. Goetze, in another study, found that a soluble nitrogen fertilizer lost 19 percent of its nitrogen to leaching. His leached percent added to that recovered is comparable to the recovery rate found in this study. Kilian states that 51% of the nitrogen from ammonium and nitrate forms of fertilizers can be recovered, again close to the figures reported here.

Ureaform and ureaform plus sugar, at the 4 lb. N level, were the only slow release fertilizer treatments to be significantly better than the other N-fertilizers used at the same rate (Table 3). This carry over effect was only in fresh and dry weight data obtained from the second cutting.

Ureaform, with and without sucrose at the 8 and 16 lb. N level, was not significantly different from or was significantly better than every other treatment (Tables 2, 3, and 4). These higher rates of nitrogen were significantly better when fresh and dry weight data were taken on termination cuttings. Kjeldahl N and growth data exhibit the same trends. No injurious effects were noted from the 16 lb. rate of ureaform N.

During the study, very few observations pointed toward a significant difference between ureaform and the same treatment plus sucrose. Even the microorganism population was not significantly better on sucrose treated soils. The microorganism population was generally larger with sucrose and high nitrogen concentrations.

Greenhouse Studies - Sterilized Soil

Sterilization of the sandy medium resulted in a release of nitrogen from the organic moieties of the soil. Several findings support this conclusion. The percentage of nitrogen in clippings from control pots was three times higher under sterilized soil conditions than under unsterilized conditions (Plate II). Secondly, Kjeldahl N data for control clippings on sterilized soil was not significantly different from the three nitrogen fertilizers used at the 2 lb. N/1000 square feet rate (Tables 5 and 6). U_2, UF_2, and M_2 were significantly better from fresh and dry weight data taken after the first cutting indicating a more efficient use of nitrogen in growth when fertilizer N was the source.

Another segment of this study that leads to the belief additional nitrogen was released by sterilization, is the burning phenomena noted on grass foliage growing in UF_{16} and UFS_{16} treated soil. Burning was not apparent when these same rates were used on unsterilized soil.

Clipping weights after the first cutting showed UF_{16} not to be significantly different from the control and UFS_2 (Table 5). UFS_{16} was significantly better in clipping weights than UF_{16}, pointing to sucrose as the important factor. A significantly higher MO population count on UFS_{16} treated soils could have assimilated excess nitrogen and decreased the severity of burning which resulted from UF_{16} treated soils. Sucrose was added to ureaform treatments in hopes of stimulating an increase in the microbial population of the soil. A larger microbial population supplied with energy to carry on assimilation and respiration should release more nitrogen from an increasingly more complex nitrogen fertilizer molecule. This additional breakdown and release was not realized in better turf quality in the short term greenhouse experiment.

Table 5: Mean ($\bar{x}$) values for Seaside Bentgrass grown in the greenhouse on sterilized soil for 39 days.

Treatment	Fresh Wt. (Grams)	Dry Wt. (Grams)	%N (Kjeldahl)	Growth (Inches)	MO Counts ($\bar{M}$)
Control	16.07 a*	2.70 a	1.53 a	3.42 a	14.7 ab
UF_{16}	17.23 a	3.67 a	4.53 f	5.25 b	18.7 abc
UFS_2	21.77 a	3.73 a	1.64 ab	5.83 bc	17.5 abc
UF_2	29.80 b	5.06 b	1.65 ab	6.58 c	11.3 a
M_2	35.56 b	5.87 b	1.79 ab	8.20 def	12.3 a
UFS_4	36.80 bc	5.80 b	2.02 bc	7.20 cde	22.2 abcd
U_2	44.40 cd	7.53 c	1.96 ab	8.25 def	13.0 a
U_4	46.80 d	7.80 cd	3.28 e	8.42 def	17.5 abc
UF_4	49.87 de	7.47 c	1.97 ab	8.25 def	12.3 a
UFS_{16}	51.16 de	7.17 c	4.34 f	7.08 cd	27.4 cd
M_4	56.93 ef	8.13 cd	2.43 cd	8.93 ef	25.8 bcd
UFS_8	62.80 fg	8.73 de	2.78 d	8.67 def	30.8 d
UF_8	67.26 g	9.53 e	2.75 d	9.58 f	16.4 abc
L.S.D.	7.6928	1.1964	0.4520	1.7401	11.2 M

*Numbers followed by the same letter are not significantly different.

Table 6: Mean ($\bar{x}$) values for Seaside Bentgrass grown in the greenhouse on sterilized soil 39 - 94 days.

Treatment	Fresh Wt. (Grams)	Dry Wt. (Grams)	%N (Kjeldahl)	Growth (Inches)	MO Counts ($\bar{M}$)
Control	8.03 a*	2.20 a	1.05 abc	2.33 a	22.1 a
U_2	11.30 ab	3.30 ab	0.90 a	2.63 ab	21.8 ab
M_2	12.73 ab	3.53 abc	1.07 abc	2.71 abc	21.7 ab
UFS_2	12.80 ab	3.23 a	1.09 abc	3.16 abcd	28.9 bc
UF_2	14.50 bc	3.86 bc	1.00 ab	2.79 abc	16.4 a
U_4	15.97 bc	4.70 bcd	0.89 a	4.08 de	17.2 a
M_4	19.26 cd	4.83 cd	1.10 abc	3.50 bcd	25.1 ab
UFS_4	21.20 d	5.70 d	1.10 abc	3.79 de	20.9 ab
UF_4	21.53 d	5.33 d	1.05 abc	3.64 cde	21.1 ab
UF_8	32.13 e	8.07 e	1.08 abc	4.50 e	20.5 ab
UFS_8	36.47 e	8.40 e	1.19 bcd	4.48 e	30.7 bc
UF_{16}	64.43 f	16.90 f	1.39 d	13.67 f	36.2 cd
UFS_{16}	64.03 f	17.23 f	1.25 cd	16.67 g	42.3 d
L.S.D.	4.9280	1.4607	0.2212	0.9626	10.1 M

*Numbers followed by the same letter are not significantly different.

Table 7: Total mean values for Seaside Bentgrass grown in the greenhouse on sterilized soil for 94 days.

Treatment	Fresh Wt. (Grams)	Dry Wt. (Grams)	%N (Kjeldahl)	Growth (Inches)
Control	24.10 a*	4.87 a	2.58 a	6.83 a
UFS_2	34.57 b	6.97 b	2.73 a	9.00 b
UF_2	34.57 b	8.93 bc	2.65 a	9.39 bc
M_2	48.30 cd	9.40 c	2.87 a	10.90 bcd
U_2	55.70 de	10.83 cd	2.87 a	10.79 bcd
UFS_4	58.00 e	11.50 d	3.11 ab	11.00 cd
U_4	59.43 e	12.50 d	4.20 d	12.49 def
UF_4	71.40 f	12.80 d	3.02 ab	11.89 de
M_4	76.20 fg	12.97 d	3.53 bc	12.43 def
UF_{16}	81.67 g	20.57 f	5.91 e	21.92 g
UFS_8	99.27 h	17.13 e	3.96 cd	13.14 ef
UF_8	99.40 h	17.60 e	3.76 cd	14.08 f
UFS_{16}	117.20 i	24.40 f	5.59 e	20.75 g
L.S.D.	9.3581	1.9831	0.5930	1.9265

*Numbers followed by the same letter are not significantly different.

Soluble urea did not exhibit the superiority over other fertilizers used at the same rate, in the same way it did on unsterilized soil. There were only isolated cases when U_2 and U_4 were significantly better. Fresh and dry weights data indicated U_2 was not significantly different from UFS_4 (only in fresh weight), U_4, UF_4, UFS_{16} (slightly burned), and M_4 (dry weight only, Table 5). U_4 was not significantly different from M_4 and UFS_8 in dry weight but significantly better in Kjeldahl nitrogen.

The percentage of nitrogen recovered in clippings from that applied was better for urea at 2 and 4 lb. N/1000 square feet than the other two nitrogen fertilizers used at the same rate. Urea and activated sewage sludge had more nitrogen recovered on sterilized soil than on unsterilized soil. Ureaform had the same or slightly less nitrogen recovered on sterilized soil, except for UF_8 treatments. A reasonable explanation for the variability of nitrogen recovery from these fertilizers may be due to the changing microorganism population.

Sterilization, besides breaking down organic matter, completely eliminates living organisms from the soil. Soil microbial populations increase once soil is exposed to the atmosphere and other contaminants. Urea is hydrolyzed to NH_4^+ and utilized by the grass. Activated sewage sludge has a microbial population, previously used to break down and flocculate raw sewage, but UF must depend on the soil microbes to release nitrogen from its organic molecular structure. Sterilization may have slowed the latter process down when bacteria or fungi capable of breaking down UF did not build up their population in the sterile soil as fast as certain autotrophic organisms.

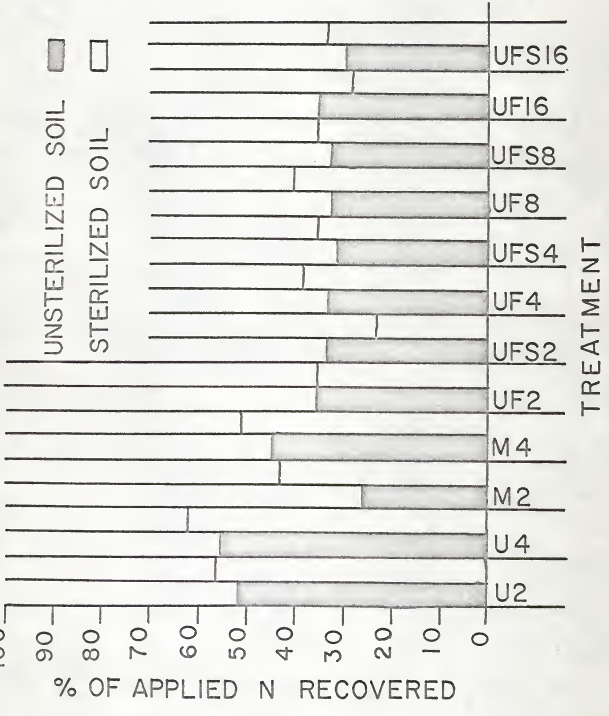
Sucrose in every case except UFS_{16} lowered the percentage of nitrogen recovered below a corresponding UF treatment without sucrose. The general

trend was for sucrose treated soils and high nitrogen concentrations to support a larger microorganism population. The build up of a microbial population on sucrose and UF after the soil had been sterilized could result in a more effective release of nitrogen from UF, if a selective population does exist and the experiment were of longer duration.

PLATE II

Nitrogen recovered expressed as a percentage of nitrogen applied.

PLATE II


UNSTERILIZED SOIL
STERILIZED SOIL
UFS16
UF16
UFS8
UF8
UFS4
UF4
UFS2
UF2
M4
M2
U4
U2
TREATMENT
100 90 80 70 60 50 40 30 20 10 0
% OF APPLIED N RECOVERED

Experimental Green

Data from the experimental green point even more emphatically toward a need for a continuous supply of nitrogen on a sandy medium. The longer duration and variable environmental conditions of the study placed an even greater stress on control plots than greenhouse studies.

Total mean ($\bar{X}$) fresh and dry clipping weights from control plots were not significantly different for U_2, UFS_2, UF_2, UF_4, UFS_4, and U_4 (Tables 8 and 9). This does not indicate that plots with 2 and 4 lbs. of N/1000 square feet were not of better quality than the control plots. Many weeds grew into control plots because the plot area was never fully covered with bentgrass. Control plots were significantly lower, by density rating, than any other treatment. Clipping weight is not a good criterion to evaluate plots which are not fully covered, since weeds cut unevenly and sand particles are always being mixed into the clippings.

Kjeldahl nitrogen percentages of the clippings and color rating for control plots were significantly lower than the other twelve treatments (Tables 10 and 12).

Urea was significantly lower rated by many criteria on the experimental green; this is in contrast to better results in the greenhouse. There were no significant differences between UFS_2, UF_2, U_2, M_2, UFS_4, UF_4, and U_4 evaluated from clipping weight data (Tables 8 and 9). Urea, 4 lb. N/1000 square feet was no better in Kjeldahl N than U_2, UF_2 and UFS_2. U_4 was not significantly different from UFS_4, UF_2, M_2, UFS_2 and U_2 by density ratings. Color ratings indicate urea at both rates used did not provide better colored turf than UF_2 and UFS_2. U_2 plots were the only set of plots not to receive a 6 rating for density during the season.

There are many reasons which might explain the lack of effectiveness of urea. The urea may have been hydrolyzed to NH_4^+ by irrigation or rain water and lost by gaseous evolution to leaching winds. This would explain a lack of effectiveness on topdressed applications (40)(41). The first fertilizer application was mixed into the top six inches of soil before seeding. The nitrogen from this application could have been leached before the young seedling roots had a chance to utilize the available nitrogen. The green was kept wet to germinate the seed and keep seedlings from drying out. Extra water probably hydrolyzed the urea mixed into the soil and the soil microorganism population changed the ammonium ion to the nitrate ion which leached out in the excess drainage (10). This seems reasonable since urea was mixed in the soil before planting in the greenhouse but made a good showing when no leaching occurred.

Urea applied at a 2 lb. N/1000 square feet is actually a relatively high concentration of soluble nitrogen material. The 4 lbs. of N is even a more dangerous rate. A 1 to 1-1/2 lb. rate of soluble N is considered a maximum safe quantity. The higher rates were used to evaluate a carry-over of nitrogen from the soluble materials. Any carry-over effect was not noted in the greenhouse, where leaching (wind and water) was not a problem.

Burning was not noted from the two rates of urea in the greenhouse but mixing of urea into the root zone may have prevented this.

Burning occurred from both urea rates applied to the green August 26, 1965. A surface application of the two high rates, insufficient watering and high temperatures probably account for the burning effect.

A late winter application of urea, at the 2 and 4 lb. rate indicated a marked improvement in plots treated with urea when growth resumed in the

spring of 1966. Plots were covering rapidly, they had good color, and there was no burning.

Urea, to be effective, would probably need to be applied every 3 weeks to 1 month at a 1/2 to 1 lb. rate in order to obtain an acceptable growth curve on a golf green. Urea could be applied at a little higher rate in the late winter to give the grass a rapid spring growth.

Activated sewage sludge, at both rates, was not significantly different from or was significantly better than the other fertilizers used at the same rate. M_2 was the only fertilizer used at the 2 lb. rate to be significantly different from the control in fresh weight of clippings and not significantly different from the 4 lb. rate of the other N-fertilizers. Dry weight data showed UF_8 and M_4 not to be significantly different (totals from Table 9).

UFS_4, M_4, and UF_8 clippings were not significantly different in Kjeldahl nitrogen percentages. M_2 was significantly better in color than other 2 lb. rates and compared favorably with UF_4, UFS_4 and M_4.

Other advantages of sludge cannot be made statistically from observations made during this study. No burning occurred from application of this fertilizer; sludge plots covered more quickly and prevented invasion by weeds; disease incidence was less prevalent in sludge plots; and these plots appeared to dry out more slowly than plots fertilized at comparable rates with urea or ureaform nitrogen fertilizers.

The slow release character and residual value of ureaform were not manifested during the first year of study on this experimental green. Lunt (28) states that there must be enough residual material in the soil to release six to seven percent of the nitrogen material per month. Plots fertilized with the highest rate of ureaform had a maximum of 32 lbs. of N/1000

square feet if the 10 percent soluble N was not lost. An amount, such as this, means that 2.24 (maximum) lb. N could be supplied per month during the summer. Similar quantities of 1.12, .56 and .28 lbs. of N would have been released per month for the 8, 4 and 2 lb. rates of ureaform N respectively.

Taking away a certain percentage of the residue each month, the soluble nitrogen lost, the amount lost in clippings and that lost to microorganism assimilation, leaves very little nitrogen for the turf when the lower rates of ureaform N were used. UF_{16} and UFS_{16} were rated consistently higher than any other fertilizer used at any other rate, bearing in mind that maximum release was 2.24 lbs. of N per month.

A second year of study may reveal better results from ureaform once the residue in the soil is built up. Building a residue too fast can result in problems since 10 percent of ureaform is soluble and when ureaform is applied at high concentration there is usually lush growth and weakened grass. Mediums with low organic content and low cation exchange capacity do not protect ureaform from microbial activity. If a select population (20) is grown which can utilize and break down urea readily, more nitrogen could be released than desired if the soil does not serve as a protector.

Nitrogen fertilizer characteristics must be taken into consideration when using a material. A comparable rate of fertilizer depends on residue, solubility, and many environmental factors (soil and atmosphere).

If a soluble fertilizer were applied a sufficient number of times during the growing season, the results from criteria used to judge turfgrass utilization of N, would not be significantly different from that obtained from a slow release fertilizer. Likewise, a slow release material could show favorable results if the residual concentration of the material is built up in the soil.

Table 8: Mean ($\bar{x}$) fresh weight of Seaside Bentgrass growing on an experimental golf green, expressed in grams.

Treatment	June 3	June 10	June 17	June 23	July 1
Control	2.90 a*	3.83 a	3.76 a	6.63 a	12.43 a
UFS_2	16.00 ab	22.46 ab	8.73 ab	22.06 ab	33.30 bc
UF_2	21.67 abc	20.87 ab	8.23 ab	22.16 ab	31.07 b
U_2	27.10 bcd	17.33 a	8.80 ab	16.73 ab	28.16 b
M_2	35.03 bcde	47.30 cd	13.20 abc	31.00 b	45.23 cd
UFS_4	40.13 cde	48.60 cd	13.63 abcd	39.63 bc	55.70 de
UF_4	47.70 def	45.13 c	21.76 bcde	35.87 bc	55.33 de
U_4	57.70 fg	37.80 bc	15.43 abcd	24.67 ab	32.60 b
M_4	66.46 gh	66.10 de	31.60 e	56.33 c	64.80 e
UF_8	90.83 h	85.80 ef	28.13 de	58.56 cd	90.86 f
UFS_8	114.70 i	90.43 fg	35.93 e	81.10 de	91.57 f
UF_{16}	129.93 i	99.13 fg	27.33 cde	87.23 e	119.23 g
UFS_{16}	134.50 i	110.46 g	32.33 e	96.97 e	114.83 g
L.S.D.	23.8284	20.1090	14.7826	23.5875	12.3098

*Numbers followed by the same letter are not significantly different.

Table 8 continued:

Treatment	July 9	July 15	July 22	July 29	August 7
Control	11.60 a	23.47 a	22.40 abc	20.90 a	15.80 a
UFS_2	21.47 b	23.87 a	21.76 abc	30.30 abc	19.37 ab
UF_2	20.23 b	27.10 ab	19.93 abc	28.53 abc	14.83 a
U_2	19.97 b	27.97 ab	22.00 abc	27.03 ab	13.93 a
M_2	24.60 bc	33.53 abc	25.36 abcd	31.27 abc	17.97 ab
UFS_4	27.47 bc	22.70 a	25.40 abcd	40.13 cd	18.40 ab
UF_4	31.53 cd	31.23 ab	25.93 abcd	33.53 bc	19.90 abc
U_4	21.50 b	32.86 abc	20.10 ab	27.80 ab	15.30 a
M_4	41.40 e	42.86 bc	35.23 cd	40.43 cd	24.70 bcd
UF_8	38.10 de	36.33 abc	35.40 cd	40.23 d	25.67 bcd
UFS_8	42.80 e	49.30 c	34.76 bcd	49.07 d	27.13 cd
UF_{16}	51.96 f	49.06 bc	60.17 d	64.28 e	31.20 d
UFS_{16}	37.23 de	42.16 bc	37.97 e	48.70 d	27.00 cd
L.S.D.	7.9019	16.2138	14.7775	11.9417	8.4425

Table 8 continued:

Treatment	August 12	August 26	August 30	September 3
Control	23.13 a	28.90 bc	15.10 bcd	6.73 ab
UFS_2	23.07 a	17.80 a	9.90 ab	2.93 a
UF_2	24.63 a	13.17 a	11.46 abc	4.87 a
U_2	29.03 abc	15.17 a	9.63 ab	6.37 a
M_2	28.57 abc	22.97 abc	16.90 cd	5.57 a
UFS_4	24.90 ab	15.47 a	11.00 ab	17.77 b
UF_4	27.47 abc	21.76 ab	14.60 bcd	6.37 a
U_4	21.73 a	14.13 a	8.00 a	2.77 a
M_4	35.26 cd	19.23 ab	16.77 cd	11.13 ab
UF_8	33.93 bcd	20.43 ab	15.27 bcd	6.80 ab
UFS_8	35.23 cd	21.57 ab	12.13 abc	5.70 a
UF_{16}	51.40 e	32.10 c	18.17 d	6.07 a
UFS_{16}	40.10 d	18.17 a	18.10 d	7.43 ab
L.S.D.	9.1406	9.8236	5.6860	11.2338

Table 8 continued:

Treatment	September 7	September 11	September 15	Totals
Control	9.70 ab	4.60 a	0.90 a	210.87 a
UFS_2	8.56 ab	5.20 a	3.17 abc	290.00 abc
UF_2	9.50 ab	6.37 ab	5.33 bc	290.00 abc
U_2	18.77 b	4.10 a	2.07 ab	283.20 ab
M_2	10.80 ab	6.87 abc	6.13 cd	401.83 bcd
UFS_4	6.67 a	6.83 abc	5.10 bc	408.60 cd
UF_4	11.77 ab	8.63 bcd	6.10 bcd	444.63 d
U_4	6.77 a	4.33 a	2.60 ab	345.93 bcd
M_4	17.73 ab	14.96 e	11.03 e	603.83 e
UF_8	14.73 ab	10.17 bcd	5.80 bcd	644.47 ef
UFS_8	11.10 ab	10.90 cde	6.67 cd	723.30 fg
UF_{16}	17.20 ab	10.77 cd	9.47 de	875.97 h
UFS_{16}	20.00 b	12.20 de	11.70 e	798.23 gh
L.S.D.	11.4870	4.1290	4.0574	119.2988

Table 9: Mean ($\bar{x}$) dry weight of Seaside Bentgrass growing on an experimental golf green, expressed in grams.

Treatment	June 3	June 10	June 17	June 23	July 1
Control	0.50 a*	1.03 a	1.80 a	2.43 a	4.77 a
UFS_2	3.67 ab	5.50 bc	2.60 ab	6.30 ab	7.70 abc
UF_2	5.03 bc	5.07 abc	2.43 ab	5.90 ab	6.73 ab
U_2	6.27 bc	4.37 ab	2.80 ab	4.67 ab	7.73 abcd
M_2	7.50 bcd	11.23 de	3.97 abc	8.50 b	9.93 bcde
UFS_4	8.90 cde	10.90 de	4.27 abc	9.77 bc	11.40 cdef
UF_4	10.60 def	10.07 d	6.13 bc	8.90 ab	11.53 def
U_4	12.40 ef	8.87 cd	4.60 abc	6.67 abc	8.03 abcd
M_4	13.87 f	14.60 ef	8.60 d	13.07 c	13.40 efg
UF_8	18.63 g	18.30 fg	7.50 cd	13.43 cd	17.33 fgh
UF_{16}	22.06 gh	22.10 g	7.70 cd	19.60 e	24.53 hi
UFS_8	23.00 gh	19.03 g	9.07 d	17.80 de	14.40 fg
UFS_{16}	25.47 h	19.43 g	8.27 d	20.60 e	21.07 hi
L.S.D.	4.2049	4.2625	3.6580	4.7433	4.0677

*Numbers followed by the same letter are not significantly different.

Table 9 continued:

Treatment	July 9	July 15	July 22	July 27	August 7
Control	4.10 a	7.20 ab	5.50 ab	9.03 abc	5.33 abcd
UFS_2	5.87 abc	6.10 a	5.53 abc	8.30 ab	4.60 abcd
UF_2	5.30 ab	7.43 ab	4.93 a	7.57 a	3.47 a
U_2	5.60 ab	7.96 abc	6.07 abcd	8.23 ab	3.97 ab
M_2	6.70 abc	9.47 abcd	6.53 abcd	9.23 abc	4.13 abc
UFS_4	7.23 abcd	6.80 a	5.46 ab	10.13 bcd	4.27 abc
UF_4	8.20 bcd	8.50 abcd	6.43 abcd	10.17 abc	4.60 abcd
U_4	6.27 abc	10.03 bcd	5.10 a	7.37 a	3.63 a
M_4	11.10 d	11.70 cde	8.67 d	10.70 bcd	5.63 cd
UF_8	9.67 cd	9.66 abcd	8.30 bcd	11.83 d	5.73 cd
UF_{16}	15.90 e	15.27 e	12.87 e	15.10 e	7.80 e
UFS_8	11.03 d	12.27 de	8.40 cd	12.40 d	6.20 de
UFS_{16}	9.20 bcd	10.17 bcd	8.27 bcd	11.20 cd	6.00 cde
L.S.D.	3.9784	3.7674	2.8750	2.4784	1.8887

Table 9 continued:

Treatment	August 12	August 26	August 30	September 3
Control	8.50 abcd	10.83 c	6.23 ab	3.17 c
UFS_2	6.73 a	5.20 ab	2.35 a	1.10 ab
UF_2	7.00 abc	4.17 a	3.30 ab	1.17 ab
U_2	8.77 abcd	4.90 ab	3.40 ab	1.50 ab
M_2	7.87 abcd	7.23 ab	5.10 ab	1.40 ab
UFS_4	6.93 ab	4.53 ab	3.10 ab	1.30 ab
UF_4	7.47 abcd	6.10 ab	3.87 ab	1.53 ab
U_4	6.33 a	4.27 a	2.40 a	0.60 a
M_4	9.50 cd	5.97 ab	4.60 ab	2.27 bc
UF_8	9.50 cd	5.90 ab	4.17 ab	1.63 b
UF_{16}	13.27 e	10.00 c	5.10 ab	1.47 ab
UFS_8	9.27 bcd	8.23 ab	3.37 ab	1.50 ab
UFS_{16}	9.80 d	4.93 ab	4.83 ab	1.87 b
L.S.D.	2.5261	2.9371	3.1776	0.9847

Table 9 continued:

Treatment	September 7	September 11	September 15	Total
Control	5.87 cd	25.67 abcde	0.33 a	78.87 a
UFS_2	2.60 a	16.00 ab	0.90 abc	76.57 a
UF_2	2.87 ab	14.00 a	1.47 bcde	75.23 a
U_2	2.63 a	18.67 abc	0.63 ab	81.37 ab
M_2	2.87 ab	23.67 abcd	1.67 cde	105.70 bc
UFS_4	2.47 a	19.00 abc	1.47 bcde	100.13 abc
UF_4	3.33 ab	23.67 abcd	1.83 de	110.63 c
U_4	2.00 a	14.67 a	0.80 abc	90.83 abc
M_4	6.40 d	36.67 e	2.87 f	146.60 d
UF_8	4.03 abc	26.33 abcde	1.60 cde	149.83 d
UF_{16}	3.60 ab	32.00 de	2.13 ef	201.70 e
UFS_8	3.93 abc	28.00 bcde	1.80 de	165.83 d
UFS_{16}	4.90 bcd	29.00 cde	2.80 f	171.70 d
L.S.D.	2.1945	12.5824	0.9628	25.1428

Table 10: Mean Kjeldahl nitrogen values (%) for Seaside Bentgrass growing on an experimental golf green.

Treatment	June 3	June 17	July 15	August 12
Control	2.20 a*	2.73 a	3.02 a	2.60 a
M_2	3.75 b	3.68 cd	3.11 bcd	3.94 c
UF_2	3.75 b	3.39 bc	3.36 abc	3.43 b
U_2	3.80 b	3.20 b	3.25 ab	3.33 b
UFS_2	3.90 b	3.73 de	3.57 abcd	3.57 b
U_4	4.10 bc	3.40 bc	3.12 ab	3.55 b
UF_4	4.30 cde	3.78 de	3.64 bcd	3.99 c
UFS_4	4.43 cde	4.04 ef	4.11 de	4.12 c
M_4	4.49 e	3.87 de	3.64 bcd	4.07 c
UF_8	4.97 e	4.37 fg	4.10 d	4.22 cd
UFS_{16}	5.07 ef	4.90 i	4.44 e	4.97 f
UFS_8	5.07 ef	4.56 gh	4.12 de	4.49 de
UF_{16}	5.40 f	4.77 hi	3.85 cd	4.70 ef
L.S.D.	0.3361	0.3050	0.5875	1.4136

*Numbers followed by the same letter are not significantly different.

Table 10 continued:

Treatment	August 26	September 7	September 15	Total
Control	2.35 a	2.38 a	2.08 a	15.89 a
M_2	4.22 b	4.93 ef	3.07 abc	27.30 cd
UF_2	3.99 b	4.17 c	2.93 bc	25.04 bcd
U_2	3.72 b	3.55 b	2.59 b	23.44 b
UFS_2	4.09 b	3.76 b	3.08 abc	25.72 bcd
U_4	4.02 b	4.47 cd	2.88 bc	24.86 b
UF_4	4.93 bcd	4.69 def	3.47 cde	37.56 d
UFS_4	4.99 bcd	4.65 def	4.67 de	30.01 e
M_4	4.62 bc	5.68 h	3.82 e	30.20 e
UF_8	6.02 cde	5.00 fg	3.50 cde	32.18 ef
UFS_{16}	6.30 de	5.22 g	4.24 e	35.14 g
UFS_8	6.03 cde	4.47 def	3.92 e	32.92 f
UF_{16}	7.38 e	4.83 ef	4.08 e	35.02 g
L.S.D.	1.4136	0.3009	0.7110	2.3036

Table 11: Mean ($\bar{x}$) density ratings for Seaside Bentgrass grown on an experimental golf green.

Treatment	May 24	June 2	June 10	June 17	June 23
Control	1.33 a*	2.00 a	3.00 a	2.67 a	3.16 a
U_2	3.67 b	4.33 b	5.00 b	4.83 b	5.00 b
UFS_2	4.00 bc	4.33 b	5.00 b	5.00 b	6.00 bcde
M_2	4.67 bcd	5.00 bc	5.33 bc	5.00 b	6.00 bcde
UF_2	4.67 bcd	5.00 bc	5.00 b	5.17 bc	5.33 bc
U_4	5.00 cde	5.00 bc	5.00 b	5.33 bcd	5.67 bc
UFS_4	5.00 cde	5.67 cd	5.33 bc	5.67 bcde	6.17 cde
UF_4	5.33 def	6.00 d	5.67 bcd	6.00 cde	6.33 cde
M_4	6.00 ef	6.00 d	6.00 bcd	6.00 cde	6.50 de
UFS_{16}	6.33 f	6.33 de	6.33 cd	6.33 e	6.67 de
UFS_8	6.33 f	6.67 e	6.00 bcd	6.17 de	6.67 de
UF_{16}	6.33 f	6.33 de	6.33 cd	6.33 e	6.83 e
UF_8	6.33 f	6.67 e	6.66 d	6.33 e	6.83 e
L.S.D.	1.0411	0.9884	1.0411	0.8393	1.0919

*Numbers followed by the same letter are not significantly different.

Table 11 continued:

Treatment	July 12	July 15	July 23	July 30
Control	3.00 a	3.00 a	3.00 a	3.00 a
U_2	5.17 b	5.33 b	5.66 b	5.50 b
UFS_2	6.00 bcd	6.00 bc	6.00 bc	6.00 bc
M_2	6.00 bcd	6.00 bc	6.00 bc	6.33 cd
UF_2	5.67 bc	6.00 bc	6.00 bc	6.00 bc
U_4	5.67 bc	6.00 bc	6.00 bc	6.00 bc
UFS_4	6.50 cde	6.50 bcd	6.50 bcd	6.50 cd
UF_4	6.67 de	6.67 cd	6.67 cd	6.67 cd
M_4	7.00 e	6.67 cd	6.67 cd	6.83 d
UFS_{16}	6.67 de	6.67 cd	6.67 cd	7.00 d
UFS_8	6.83 de	6.67 cd	7.00 d	7.00 d
UF_{16}	6.83 de	7.00 d	7.00 d	7.00 d
UF_8	7.00 e	7.00 d	6.83 d	7.00 d
L.S.D.	0.9115	0.7238	0.7238	0.7721

Table 11 continued:

Treatment	August 8	August 13	September 23	Total
Control	3.00 a	3.33 a	1.33 a	31.16 a
U_2	5.50 b	5.67 b	4.00 b	63.50 b
UFS_2	6.00 bc	6.00 bc	6.33 bc	70.33 bc
M_2	6.50 cd	6.33 bcde	7.00 bc	72.83 c
UF_2	6.00 bc	6.17 bc	7.00 bc	71.33 bc
U_4	6.50 cd	6.50 cde	6.33 bc	72.33 c
UFS_4	6.33 cd	6.83 de	6.33 bc	76.33 cd
UF_4	6.83 d	6.83 de	7.00 bc	81.33 de
M_4	6.83 d	7.00 e	7.33 d	84.00 de
UFS_{16}	6.83 d	7.00 e	6.77 bc	82.83 de
UFS_8	7.00 d	7.00 e	7.00 bc	86.00 e
UF_{16}	7.00 d	7.00 e	7.00 bc	87.00 e
UF_8	7.00 d	7.00 e	7.00 bc	89.00 e
L.S.D.	0.7837	0.7361	1.0057	8.5683

Table 12: Mean ($\bar{x}$) color ratings for Seaside Bentgrass grown on an experimental golf green.

Treatment	June 23	July 12	July 15	July 23
Control	1.00 a*	2.00 a	1.33 a	1.33 a
U_4	2.00 b	2.67 ab	2.67 b	2.33 b
U_2	2.00 b	3.00 bc	2.33 b	2.33 b
UF_2	2.00 b	2.67 ab	2.33 b	2.66 b
M_2	2.67 bc	4.00 d	4.00 de	3.00 bc
UFS_2	2.67 bc	3.67 cd	2.66 b	3.00 bc
UFS_4	3.00 c	3.67 cd	3.66 cd	4.00 d
UF_4	3.00 c	4.00 d	3.00 bc	4.00 d
M_4	3.33 cd	4.00 d	4.00 de	3.66 c
UF_8	3.67 cde	5.00 e	4.67 def	4.00 d
UF_{16}	4.00 de	5.00 e	5.00 f	5.00 e
UFS_{16}	4.33 e	5.00 e	5.00 f	5.00 e
UFS_8	4.33 e	5.00 e	5.00 f	4.66 de
L.S.D.	0.8224	0.7112	0.7112	0.9312

*Numbers followed by the same letter are not significantly different.

Table 12 continued:

Treatment	August 8	August 13	Total
Control	1.00 a	1.00 a	8.00 a
U_4	1.33 ab	1.33 a	13.00 b
U_2	1.66 bc	1.66 ab	13.33 bc
UF_2	1.00 a	1.00 a	12.67 b
M_2	2.66 d	2.66 cd	19.33 de
UFS_2	1.33 ab	1.33 b	15.67 bc
UFS_4	3.00 de	3.00 de	20.67 de
UF_4	2.66 d	2.33 bc	18.67 d
M_4	3.00 de	3.00 de	21.67 e
UF_8	3.66 e	3.67 e	25.00 f
UF_{16}	5.00 f	5.00 f	29.00 g
UFS_{16}	5.00 f	5.00 f	29.33 g
UFS_8	3.66 e	3.67 e	27.00 fg
L.S.D.	0.7112	0.7112	2.5784

A nitrogen fertilizer could be more than just a nitrogen source. Cost accounting evaluations on nitrogen utilization per year, savings in labor, savings in materials (herbicides and fungicides), savings in storage, and savings in irrigation water would better explain why one nitrogen fertilizer is better for a given use.

Conclusions

Three nitrogen fertilizers were used on a sandy medium (85.6% sand) and Seaside bentgrass was grown as an indicator for nitrogen utilized from these materials.

1. Urea (45% N) was quickly available in the greenhouse studies but exhibited very little carry-over of N when high rates of nitrogen were used.

2. Urea (45% N) was leached by wind and rain from the experimental green and was relatively ineffective.

3. Activated Sewage Sludge (6% N) was not significantly different from or was significantly better than other fertilizers used at the same rate on the experimental green.

4. Ureaform must be applied at higher rates or combined with a more soluble fertilizer until a residue of this material can be built up in the soil.

5. If nitrogen fertilizer characteristics are considered, and proper allowances made for release rate, conversion to a usable form, and residual properties, there should be no difference in turf quality resulting from the use of nitrogen.

6. A system comparing savings in labor, herbicides, fungicides, and irrigation water balanced against nitrogen utilization would better compare the over all aspects of a nitrogen fertilizer. Nitrogen is nitrogen if used properly, but a carrier can increase the value of a fertilizer material even more than nitrogen itself.

Literature Cited

(1) Anonymous. Ureaform tests in 3rd year. Agr. Chem., 13(9): 59, 1958.

(2) Anonymous. Urea-form fertilizers give even growth. Crops and Soils, 13(6): 22, 1961.

(3) Association of Official Agricultural Chemistry. Methods of Analysis. Eighth Edition, 3.10: 30-31, 1955.

(4) Agronomy 537 - Soil Physics. Hydrometer method of particle size analysis. Kansas State University, Agronomy Department. Laboratory Exercise III, 1964.

(5) Armiger, W. H., Ian Forbes Jr., R. E. Wagner and R. O. Lundstrom. Urea-form - a nitrogenous fertilizer of controlled availability: experiments with turfgrasses. Amer. Soc. of Agron. Jour., 40: 342-356, 1948.

(6) Armiger, W. H., K. G. Clark, F. O. Lundstrom, and A. E. Blair. Urea-form: Greenhouse studies with perennial ryegrass. Amer. Soc. of Agron. Jour., 43: 123-127, 1951.

(7) Baumgartner, L. L. Ureaform produces superior sod-building fertilizers. Agr. Chem., 13(12): 64, 1958.

(8) Bear, Firman E. Soils and Fertilizers, John Wiley and Sons, Inc., New York, 64-79p, 1959.

(9) Blaser, R. E. and R. E. Schmidt. The ecology of nitrogen activity in turf soils. The Golf Course Reporter, 32(4): 12-22, 1964.

(10) Bredakis, E. J. Leachable nitrogen from soils incubated with turfgrass fertilizers. Amer. Soc. of Agron. Jour., 55: 145-147, 1963.

(11) Clark, K. G. Urea-form: new nitrogen fertilizer. Crops and Soils, 4(8): 14-17, 1952.

(12) Clark, K. G. and T. G. Lamont. Correlation between nitrification and activity indexes of ureaformaldehyde in mixed fertilizers. Assoc. Offici. Agr. Chem. Jour., 43: 504-506, 1960.

(13) Clark, K. G., J. Y. Yee and K. S. Love. Urea-form - a new synthetic nitrogen fertilizer, preparation and properties. Bibliog. Ind. and Eng. Chem., 40: 1178-83, 1958.

(14) Clark, L. J. and W. L. Hill. Occurence of Manganese, Copper, Molybdenum, and Cobalt in phosphate fertilizers and sewage sludge. Assoc. Offici. Agr. Chem. Jour., 41: 631-637, 1958.

(15) Duich, Joseph M. Agronomic aspects of ureaform fertilizers. Proc. of Fert. Ind. Round Table, 1962.

(16) Ernst, J. W. and H. F. Massey. The effects of several factors on volatilization of ammonia formed from urea in the soil. Soil Sci. Soc. of Amer. Proc., 24: 87-90, 1960.

(17) Ferguson, Marvin C. After five years: the green section specifications for a putting green. USGA Green Section Record, 3(4): 1-7, 1965.

(18) Fuller, W. H. and K. G. Clark. Microbial studies of ureaformaldehyde preparations. Soil Sci. Soc. of Amer. Proc., 12: 198-202, 1947.

(19) Goetze, Norman Richard. Heavy nitrogen fertilization of cool season turf grasses. Diss. Abs., 21(1): 2-3, 1960.

(20) Grau, F. V. Principles involved with residual nitrogen. Midwest Regional Turf Conference Proceedings. 49-51, 1963.

(21) Hatfield, W. D. and Edward Bartow. The value of activated sludge as a fertilizer. Illinois State Water Survey, University of Illinois, p. 336-347, 1915.

(22) Hays, J. T., W. W. Haden and L. E. Anderson. Nitrification fractions from commercial ureaforms. Jour. of Agr. and Food Chem. 13(2): 176-179, 1965.

(23) Jackson, James E., J. M. Good and G. W. Burton. Nitrogen sources for bermudagrass greens. The Golf Course Reporter, 31(4): 41-42, 1963.

(24) Kender, W. J. and N. F. Childers. Urea-formaldehyde as a source of nitrogen for horticultural crops. Masters Thesis, Rutgers University, 1959.

(25) Kilian, Kenneth Clarence. Use of urea-formaldehyde and other slowly available forms of nitrogen for grass. Diss. Abs., 24(9): 3485-3486, 1964.

(26) Long, F. L. and G. M. Volk. Availability of nitrogen contained in certain condensation products of reaction of urea with formaldehyde. Amer. Soc. of Agron. Jour., 55: 155-158, 1963.

(27) Lunt, H. A. The case for sludge as a soil improver. Water and Sewage Works, 100: 295-301, August 1953.

(28) Lunt, H. A. Sewage sludge improves soil. Crops and Soils, 13(2): 14-15, 1961.

(29) Lunt, R. O. Fertilizer products and practices. The Golf Course Reporter, 31(4): 34, 1963.

(30) Martin, W. P., T. F. Buehrer and A. B. Caster. Threshold pH values for the nitrification of ammonia in desert soils. Soil Sci. Soc. of Amer. Proc., 7: 223-228, 1942.

(31) Mruk, C. K., A. J. Wisniewski, and J. A. DeFrance. A comparison of urea-formaldehyde materials for turf grass fertilization. Agr. Chem., 12(9): 49-50, 1957.

(32) Muller, J. F. The value of raw sewage sludge as a fertilizer. Soil Sci. Soc. of Amer. Proc., 28: 432-435, 1929.

(33) Musser, H. B. and J. M. Duich. Response of creeping bentgrass putting green turf to urea-formaldehyde compounds and other nitrogenous fertilizers. Amer. Soc. of Agron. Jour., 50: 381-384, 1958.

(34) Niles, A. H. Sludge for fertilizer. Water Works and Sewerage, 91: 181-182, 1944.

(35) Pair, John C. Growth studies of five bentgrasses. Masters Thesis, Kansas State University, 1961.

(36) Rehling, C. J. and E. Truog. Activated Sludge; Milorganite; Constituents, elements, and growth producing substances. Ind. and Eng. Chem. Anal. Ed., 11: 281-283, May 1939.

(37) Rudolfs, W. Fertilizer and fertility value of sewage sludge. Water works and Sewerage, 87(12): 575-578, 1940.

(38) Scarsbrook, C. E. Urea-formaldehyde fertilizer as a source of nitrogen for cotton and corn. Soil Sci. Soc. Amer. Proc., 22: 442-445, 1958.

(39) Volk, G. M. Nitrogen sources for maintenance of turfgrasses. The Golf Course Reporter, 22(8): 5-8, 1954.

(40) Volk, G. M. Volatile loss of ammonia following surface applications of urea to turf or bare soil. Amer. Soc. of Agron. Jour., 51: 746-749, 1959.

(41) Volk, G. M. Gaseous losses of ammonia from surface-applied nitrogenous fertilizers. J. Ag. and Food Chem., 9: 280-283, 1961

(42) Volk, G. M., W. H. Kelley, and W. G. Blue. Recovery of nitrogen from several sources by oats and millet. Soil and Crop Sci. Soc. Florida Proc., 19: 379-385, 1959.

(43) Wagner, G. H. Nitrogen losses from soils fertilized with different nitrogen carriers. Soil Science, Soc. of Amer. Proc., 85: 125-129, 1958.

(44) Wisniewski, A. J. Results of ureaform fertilization on lawn and fairway turf. Amer. Soc. of Agron. Jour., 50: 575-576, 1958.

(45) Yee, J. Y. and K. S. Love. Nitrification of urea-form reaction products. Soil Sci. Soc. Amer. Proc., 11: 389-392, 1947.

Acknowledgements

The author wishes to express his sincere gratitude to Dr. Ray A. Keen, professor of horticulture, Kansas State University, for his patience and for his guidance during the experimental study and in the preparation of this thesis.

My appreciation is also expressed to the other members of my advisory committee, Dr. Robert P. Ealy, chairman of the Department of Horticulture and Director of Landscape Architecture; and Dr. Roscoe Ellis Jr., professor of Agronomy, Kansas State University, for their encouragement and thoughtfulness during this program.

My gratitude goes to the Department of Horticulture, Kansas State University, who provided the opportunity and funds for my graduate research assistantship.

To Dr. J. O. Harris, professor of soil microbiology I am indebted for very helpful consultation.

Fertilizer manufacturers and consultants who helped make this study possible are gratefully acknowledged.

To my wife, Melody, I am especially grateful for her splendid cooperation in typing the final copy of this thesis. Her heartening words made the completion of this endeavor possible.

NITROGEN UTILIZATION FROM SANDY MEDIUMS

by

FRANCIS BRENT HOADLEY

B. S., University of Vermont, 1964

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment

of the requirements for the degree

MASTER OF SCIENCE

Department of Horticulture

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1967

The purpose of this study was to investigate nitrogen utilization from urea (45% N), activated sewage sludge (6% N), ureaform (38% N) and ureaform (38% N) plus sucrose.

Agrostis palustris, variety Seaside bentgrass, was grown on a soil medium consisting of 85.6% sand. Studies were conducted in the greenhouse (using the sandy soil unsterilized and sterilized) and on an experimental green.

Fresh and dry weights, kjeldahl nitrogen, growth (density) ratings, and color ratings were criteria used to evaluate nitrogen utilization by the grass. A population count was made to determine the effect different sources of N have on the microbial population of the soil.

Sterilization of the sandy medium for the greenhouse study released nitrogen from the organic moieties in the soil complex. Controls had higher fresh and dry weights, kjeldahl N and growth ratings on sterilized soil. Ureaform applied at the rate of 16 lb. N/1000 sq. ft. burned the grass foliage on sterilized soil but no burning occurred on unsterilized soil. The same rate of ureaform did not burn the grass as severely when sucrose was applied with the fertilizer at the rate of 20 lb./1000 sq. ft.

The addition of sucrose to those pots of soil treated with the highest rates of ureaform resulted in a significantly higher microbial population, when compared to pots of soil receiving just high rates of ureaform N. Microorganisms may have fixed some of the excess N released by sterilization and accounted for a less severe foliage burn on pots treated with sugar.

The studies indicate that rates may be more important than the initial source of N. Each rate of N was significantly better than the lower rates.

Greenhouse studies point out the need for careful consideration of N-fertilizer characteristics. Soluble urea released nitrogen quickly and

turf growing in soil treated with it was significantly better on the first cutting date than turf growing on soil treated with any other source of N at the same rate. By the second harvest this advantage had been lost over the other more slowly available fertilizers.

Results of the study express a need for more than turf response to evaluate the relative value of different sources of N applied at the same rate. Urea was significantly lower rated in many criteria judged on the experimental green and this is contrasting to greenhouse results. Sewage sludge was not significantly different from or was significantly better than other fertilizers used at the same rate on the experimental green. Fewer weeds, less disease incidence and less water loss was apparent on sludge plots.